Snowmass EF Restart Workshop DM summary plot session: guide for discussion

2021/08/31

Dark matter complementarity in Snowmass

Input also from Suchita Kulkarni, Rebeca Gonzalez Suarez

- We are witnessing a shift in how we think about searches for dark matter.

- We are in an exploratory phase where new ideas can be implemented on short timescales (many examples in RF06), operating alongside longer-term projects (eg HL-LHC, FCC, Gen-3 direct detection)
  → Key point for DM discoveries and characterization: **work together**!

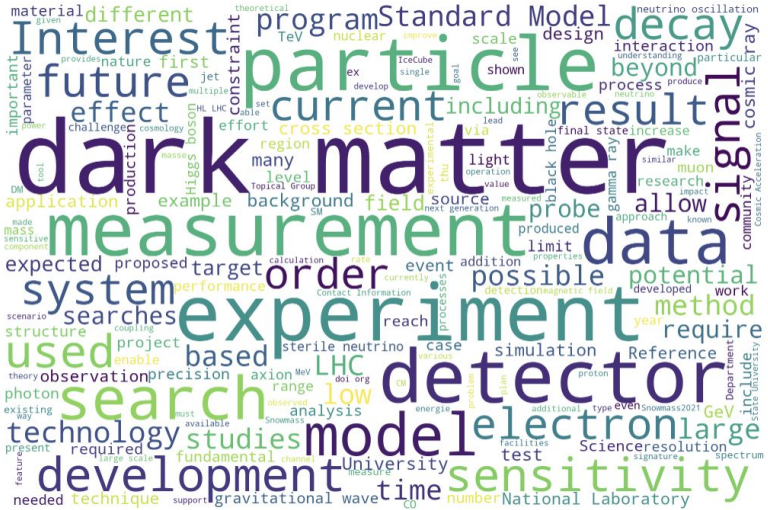
- Snowmass efforts towards a discussion of dark matter complementarity ↔ **cross-frontier**
  a. Want to build on work ongoing towards the whitepapers in the **individual TGs**
  b. Potential complementarity whitepaper that refers to work & contextualize it (no duplication!)

https://gordonwatts.github.io/snowmass-loi-words

Word Clouds

Word clouds are made by looking at the word frequency in the LOI's. The more frequent the word, the larger the font-size in the word cloud.

All LOI's



Limiting the scope: EF10 (x) RF06

- RF06: **portals** rather than interpretations
  - not all portal models have a DM interpretation...
  - ...but many different portal models can include a DM particle
    i. To be developed further: “what is DM particle”? Tie to the relic density? If so which kind of relic?

- Given the time we have, we cannot be comprehensive with models/experiments
- Wish from EF10: pick 1-2 models to show how low / high energy experiments in the next decade can explore different regions of phase space
  - Use those as simple/clear examples of **complementarity**

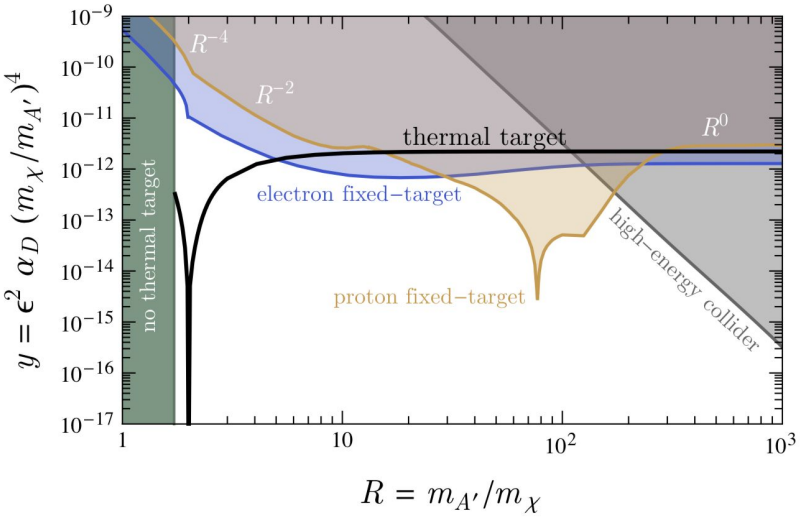
- Which models from RF06 table?
  - A possible opportunistic choice (because we can rely on existing work):
    i. Vector portal / dark photon
    ii. Scalar portal (possibly with a Higgs - see next discussion item)

More specific questions

Ideas and text from https://arxiv.org/pdf/2003.03379.pdf and Natalia Toro's talk @ Snowmass 18/06/2020

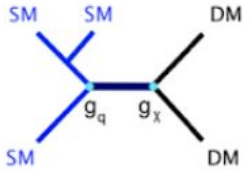
	DM Production	Mediator Decay Via Portal	Structure of Dark Sector
Vector	m_χ vs. y $[m_{A'}/m_\chi=3, \alpha_D=.5]$ **$m_{A'}$ vs. y** [α_D=0.5, 3 m_χ values] ~~m_χ vs. α_D $[m_{A'}/m_\chi=3, y=y_{th}]$~~ m_χ vs. $m_{A'}$ [α_D=0.5, $y=y_{th}$] *Millicharge m vs. q*	$m_{A'}$ vs. ϵ [decay-mode agnostic] ***$m_{A'}$ vs. ϵ [decays]***	**iDM m_χ vs. y** $[m_{A'}/m_\chi=3, \alpha_D=.5]$ **(anom connection)** **SIMP-motivated cascades [slices TBD]** $U(1)_{B-L\ /\ \mu-\tau\ /\ B-3\tau}$ (DM or SM decays)

- Plot proposal (again from Natalia Toro + other RF06 participants)



The same new physics scale can come from either:
light, weakly coupled mediator (accelerator experiments)
or
heavy, strongly coupled mediator (collider experiments)

Colliders:
DM (invisible) final stat



- Can we work together on a similar plot?
  - We will most likely need help with "translation" of our own results / versions of vector portal, both for e+e- and for pp colliders
  - Is this doable with Darkcast?

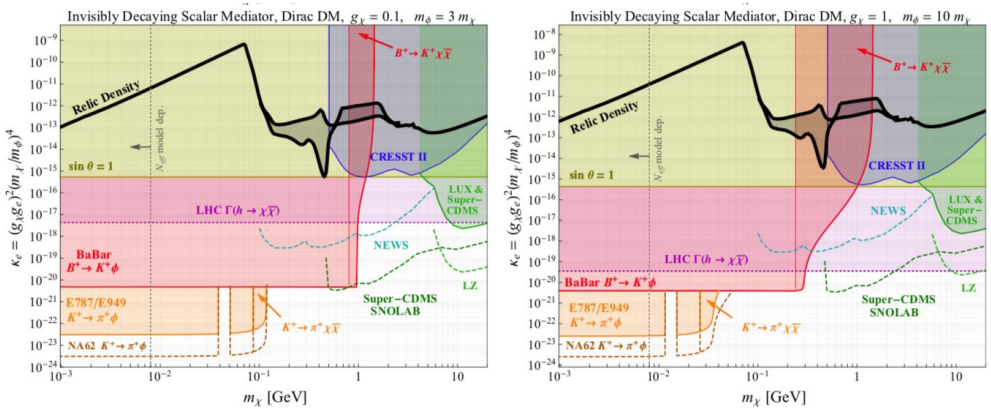
More specific questions

From a discussion between FIPS and DMWG organizers

Scalar	m_χ vs. sinθ [λ=0, fix m_S/m_χ, g_D] (thermal target excluded 1512.04119, should still include) Note secluded DM relevance of S→SM of mediator searches	m_S vs. sinθ [λ=0] m_S vs. sinθ [λ=s.t. Br(H→ϕϕ ~10^{-2})]?	Dark Higgs-sstrahlung (w/vector) scalar SIMP models? Leptophilic/leptophobic dark Higgs?

- Another idea for plot (from Gordan Knajic + other RF06 participants, from 1512.04119)
  - Key points for complementarity: show different couplings & increase mass range

y axis not that immediate to understand in these/previous plots?



See also next part of today's discussion on Higgs to invisible / Higgs portals

Old material from last “complementarity” Snowmass meeting before the break (Dec 2020)

Two goals for the Snowmass complementarity effort

1. Split the broad DM question in different **themes**
   - This is mainly an **organizational question**:
     - In the same way as we had sessions at CPM, we need to have **focused discussions** on smaller parts of the problem to make progress
   - A theme is used to facilitate discussion of subsets of people from different TGs in focused workshops (e.g. making summary plots from different frontiers)
   - A theme is not used to give a particular emphasis to a kind of DM/detection technique in the final whitepaper
   - Goal to **converge on themes today**

2. [longer term] Connect the themes into a big picture
   - Ideas discussed so far:
     - Dark matter flowchart [N. Blinov, N. Toro, others]
     - Dark matter mountain [N. Toro]
     - Dark matter landscape as peaks [S. Gardner]
   - This discussion will continue regularly alongside the workshops on individual themes

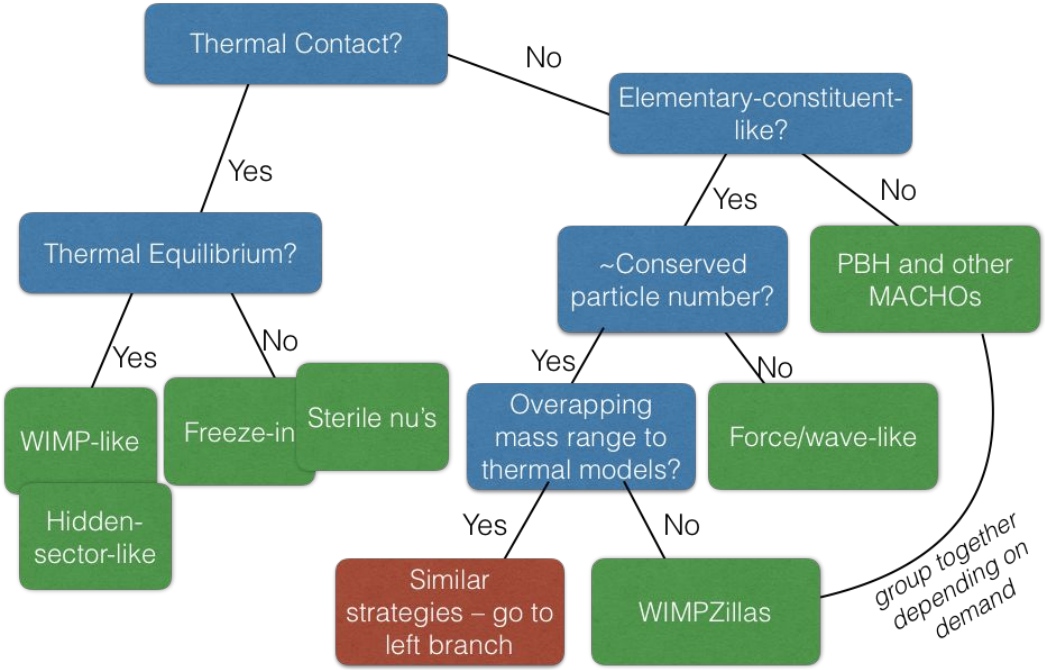
What happens next?

1. Split the overall “DM problem” into *DM themes* following a broad-strokes DM flowchart. One example from the discussion on 09/11/20 is in the notes [link], but others have been invited on the mailing list to come up with different ideas.
   a. Options will be discussed and finalized **today** and distributed to Topical Group conveners for feedback.
2. Once themes are settled, find “responsibles” for organizing each theme’s workshop
3. Subdivide in groups to develop the complementarity story for each theme (e.g. break-out workshops/sessions) [December 2020 to February 2021]
   a. In parallel, have meetings about the complementarity landscape/big picture
4. Regroup to build a big picture [February/March 2021]
5. Present the plan & work at the APS meeting [April 2021]

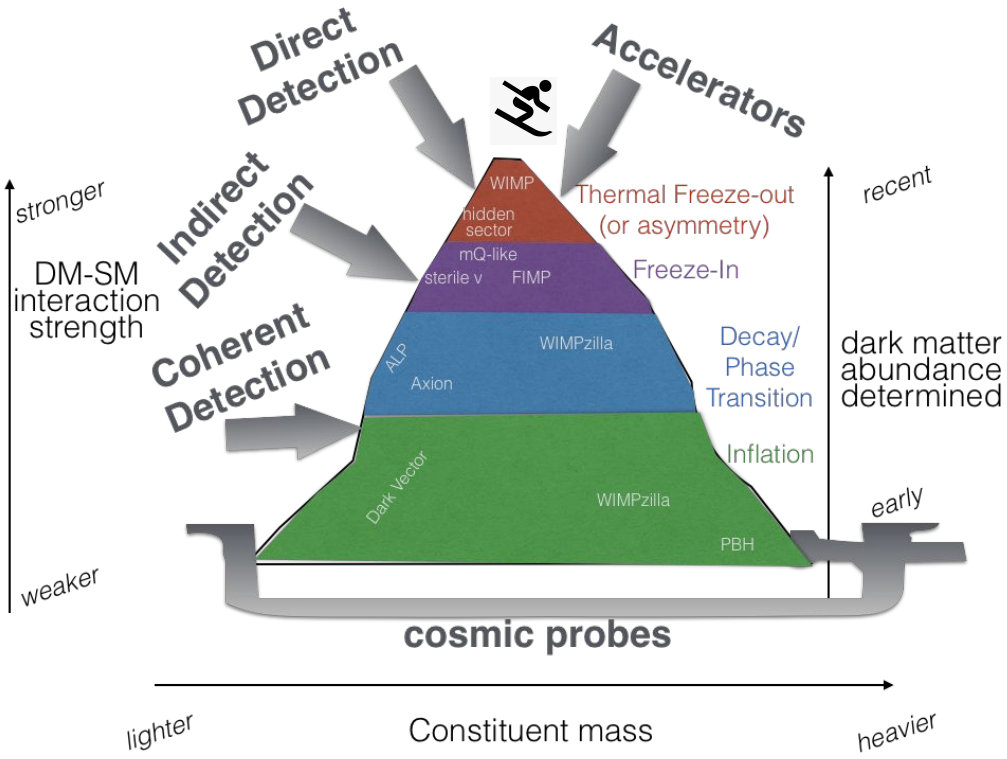
An initial proposal for themes

1. Thermal WIMP DM
2. Thermal, much lighter than WIMP DM
3. Non-thermal freeze-in DM (including sterile neutrino, hidden sectors with very light mediators, TeV-scale particles a la gravitino)
4. Wave-like DM, axions and hidden photons (as DM and as mediator)
5. Very heavy DM (both particles and macroscopic objects)
6. DM with gravitational interactions only
7. DM that we don't yet know about / for which we don't have a theory

Dark matter flowchart [N. Toro, A. Berlin, N. Blinov]



Dark matter mountain [N. Toro]



Dark matter Aspen landscape [S. Gardner]